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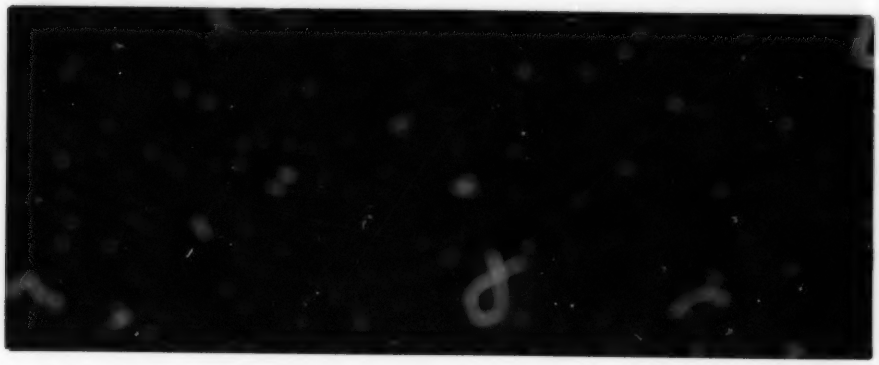

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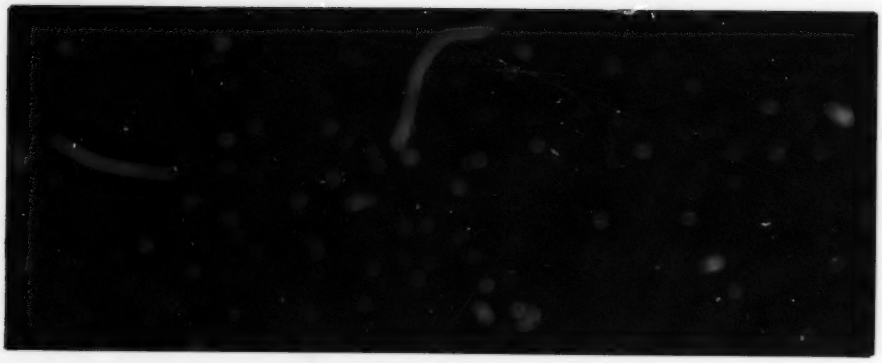

Final Report

2.2-22

The Nutritive Value of Awned and Non-Awned Wheat Chaff and Their Responses to Ammoniation

Funded by

The Agriculture Development Fund

2.2–22

Final Report

THE NUTRITIVE VALUE OF AWNED AND NON-AWNED, WHEAT CHAFFS AND THEIR RESPONSES TO AMMONIATION

by

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ABSTRACT

Phase I

No effect of ammoniation was observed on Wakooma (rough-awned) or Katepwa (non-awned) chaff by either dry grinding (fragility test) or wet grinding (mastication test). Sheep trials indicated that ammoniation, especially under plastic, improved the digestibility and consumption of both types of chaff. Steer trials on the same materials one year later were confounded by a possible reversal of the ammoniation reaction and contamination with excessive soil. Wakooma chaff ammoniated under a cover showed the most improvement and gave the best performance.

Phase II

The animal trials were again confounded by excessive soil in the chaff and inadequate moisture during ammoniation of Wascana (rough-awned) chaff. These awns do not appear to affect untreated chaff consumption by cattle, but may be a factor in reduced chaff consumption by sheep. The component nutrient digestibilities of ammoniated Columbus (non-awned) chaff were equivalent to those for brome hay, but were not reflected in consumption. Adequate moisture (20%) is absolutely necessary during the ammoniation reaction to improve the digestible energy available to both sheep and cattle. One finding of this work is that it is dangerous to use sheep intake and digestibility data for chaff to predict nutritive values of the chaff for cattle.

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INTRODUCTION

During the past 10 years, many laboratory and digestibility studies have been conducted on ammoniated crop residues and low to medium quality hays. However, very few performance studies have been conducted to determine the value of ammoniated straw or chaff as the basis for a cow maintenance ration or a calf growing ration. It has been demonstrated that chaff from cereal crops may be a valuable ruminant feed from a nutritional standpoint.

In addition, while ammonia treatment of chaff has been shown to be beneficial from standpoints of increasing nutritive value and also destruction of seed viability, there are several unresolved problems in the ammoniation process, specifically whether stacks require plastic covering and/or the consequences of not covering stacks. A major deterrent to ammoniation has been the use of plastic covers, and if simpler methods could be applied, the ammoniation process would be more widely practised.

Thirdly, with increasing incidence of awned varieties of cereals, the potential for use of this material as a livestock feed has increased, but the presence of awns renders chaff relatively unpalatable to animals. Our preliminary studies with sheep indicate that ammoniation renders chaff from rough-awned wheat cultivars, such as Norstar Winter Wheat or HY 320, much more acceptable to animals and the resulting increase in intake is very substantial (Coxworth 1986). In subsequent feeding trials with beef cows there did not appear to be the same degree of reluctance to consume awned

chaff in relation to non-awned chaff. These observations suggest that there may be substantial differences between beef cattle and sheep in acceptance of chaff from awned cultivars, thus prejudicing the applicability of sheep intake/digestion data to cattle. The present studies were undertaken to attempt to determine how ammoniation physically affected both the awned chaff and non-awned chaff, and to compare intakes, and digestibilities of both types of chaff, untreated and ammoniated with and without a plastic cover, using sheep and steers. In addition, the nutritive values of the chaffs were assessed by means of a feeding trial with pregnant beef cows.

PHASE I - 1987-88 CROP YEAR

LABORATORY STUDY (1987 Crop Year)

MATERIALS AND METHODS

Awns

Twenty kg of Norwin winter wheat (rough-awned cultivar) was harvested by hand from a Crop Science plot on the Kernen Farm, University of Saskatchewan in the fall of 1987. The material was dried in a forced air drier at 40°C and threshed through a stationary Hege combine at the Saskatoon Experimental Station of Agriculture Canada to yield 2 kg of awns. Four 100 g samples of these awns were treated with 3% anhydrous ammonia at 20% moisture and 20°C for three weeks. Representative samples of treated and untreated awns were submitted to the Feed Testing Laboratory (FTL) of the University of Saskatchewan for crude protein (CP) analysis (AOAC 1973) and duplicate samples were sent to the Swift Current Research Station of Agriculture Canada for in vitro organic matter digestibility (IVOMD) analysis (Troelsen 1970). The remainder of each sample was retained for fragility and mastication tests.

Chaff

Four replicates of each of several cereal cultivars were harvested from Agriculture Canada plots at the Saskatoon Experimental Station in the fall of 1987. The replicates were dried, 35 g of each were ammoniated and sub-samples were submitted for analysis as described for the Norwin winter

wheat awns. The barley cultivars harvested were Bonanza, Scout, Harrington, Leduc, Ellice and Argyle. The wheat cultivars harvested were Roblin, Columbus, Neepawa, Leader, Sceptre, HY 320, Katepwa, and Wakooma (durum). The remainder of each sample was retained for fragility and mastication tests.

Fragility Test

A fragility test was developed by Zorrilla-Rios et al. (1984) to attempt to determine why straws from different cultivars were digested in the rumen at different rates. The test was established to determine the relative ease that straws from different cultivars would break up when ground under specific conditions. Two g of straw was ground for 20 sec in a Moulinex 228.113 coffee grinder and sieved through 0.5 and 1 mm screens for 5 min. The weight of straw contained between the two sieves is expressed as a percentage of the total sample. Significance was determined using a one-way analysis of variance.

A sample of rough-awned chaff was treated with 3% anhydrous ammonia at 20°C and 20% moisture for 3 weeks. Six untreated and 6 ammoniated samples were tested to evaluate the fragility test.

Mastication Test

An artificial masticator was designed at the Swift Current Experimental Station of Agriculture Canada by Troelsen and Knipfel several years ago

(Knipfel 1987). Ten g of chaff, emersed in a specified volume of water in a 1 l plastic beaker, was ground between a set of gears for a specified time. The resulting mixture was wet screened through a series of screens for a specified time, and dried in an oven. The weight of sample trapped between screens was recorded and expressed as a percentage of the mean total recovery. Significance was determined using a one-way analysis of variance.

RESULTS AND DISCUSSION

Nutritional Value of Cultivars and Awns

The analytical results confirm that barley chaff is of superior nutritional value than wheat chaff both before and after ammonia treatment, and that wheat chaff responds better to ammonia treatment than does barley chaff (Table 1, Figs. 1, 2, 3, 4). Pure Norwin awns are inferior to both barley and wheat chaff in nutritional value but do respond well to ammonia treatment (Table 1). These results indicate that both ammoniated wheat and barley chaff should provide adequate CP and energy to over winter pregnant cows when supplemented with vitamins and minerals. Both protein and energy supplementation would be required for a calf growing ration.

Table 1 Effect of ammoniation on the crude protein content and digestibility of wheat and barley chaff.

Cultivar	Untreated %CP	Untreated %ASH	Untreated % IVOMD	Ammoniated % CP	Ammoniated % ASH	Ammoniated % IVOMD
Barley						
Scout	5.3^{b}	12.0^{g}	48.7^{ab}	11.6^{a}	9.4^{cd}	61.9^{bc}
Bonanza	8.6^{f}	9.6^{abcd}	61.9^{g}	13.6^{d}	8.2^{a}	67.1^{ef}
Harrington	7.0^{d}	10.7^{def}	58.3^{f}	12.3^{ab}	9.0^{bc}	66.2^{e}
Leduc	8.3^{f}	9.4^{abc}	62.7^{g}	13.6^{d}	8.4^{ab}	67.1^{ef}
Ellice	6.8^{d}	11.1^{ef}	58.5^{f}	12.2^{ab}	10.4^{fg}	64.5^{de}
Argyle	7.9^{e}	10.6^{cdef}	59.2^{f}	13.8^{d}	8.2^{a}	69.0^{f}
Mean	7.3	10.6	58.2	12.9	8.9	66.0
Average Increase	-	-	-	5.5	-	7.8
Wheat						
Roblin	5.1^{ab}	10.9^{ef}	47.8^{a}	11.5^{a}	10.6^{fg}	59.6^{a}
Columbus	5.5^{b}	10.1^{bcde}	50.4^{c}	12.8^{bcd}	9.8^{de}	60.3^{ab}
Neepawa	5.8^{c}	8.7^{a}	51.1^{cd}	13.6^{d}	8.2^{a}	62.1^{bc}
Leader	5.5^{b}	9.2^{ab}	49.5^{bc}	12.5^{abc}	9.4^{cde}	59.2^{a}
Septre	5.7^{c}	10.8^{def}	54.5^{e}	12.3^{ab}	11.2^{h}	60.4^{ab}
HY 320	4.8^{a}	11.6^{f}	50.2^{c}	11.6^{a}	11.1^{gh}	59.1^{a}
Katepwa	5.8^{c}	9.5^{abcd}	50.3^{c}	13.4^{cd}	8.9^{bc}	64.0^{cd}
Wakooma	5.1^{ab}	10.4^{cdef}	52.0^{a}	12.3^{ab}	10.1^{ef}	59.7^{a}
Mean	5.4	10.2	50.7	12.5	9.9	60.6
Average Increase	-	-	-	7.1	-	9.8
Norwin Awns[1]	2.4	8.9	44.7	8.3	8.3	53.1
Significance of Cultivar Effect	<0.001	<0.05	<0.001	<0.10	<0.001	<0.001

1 not included in statistical analysis

means in the same column with the same letter are not significantly different ($p = 0.05$)

CP - crude protein

IVOMD - in vitro organic matter digestibility

Fig. 1. Effect of ammonia on OMD

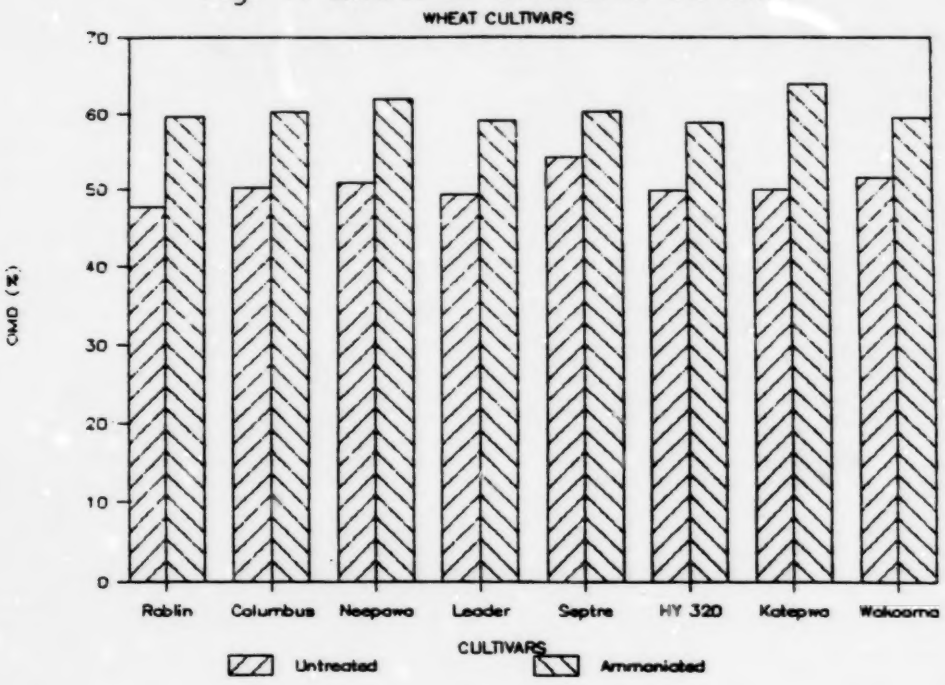


Fig. 2. Effect of ammonia on CP

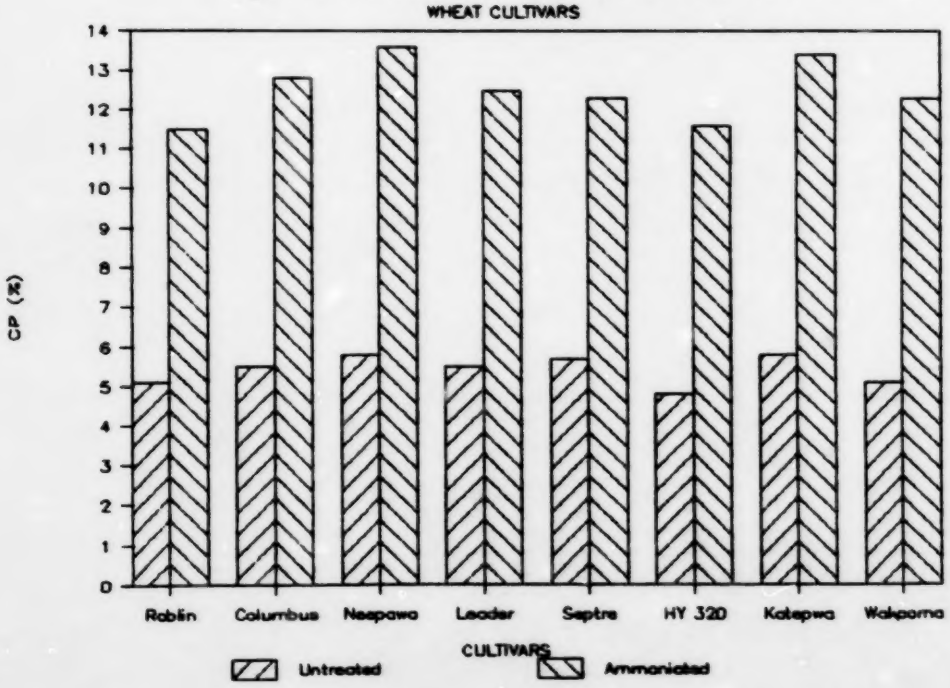


Fig. 3. Effect of ammonia on OMD

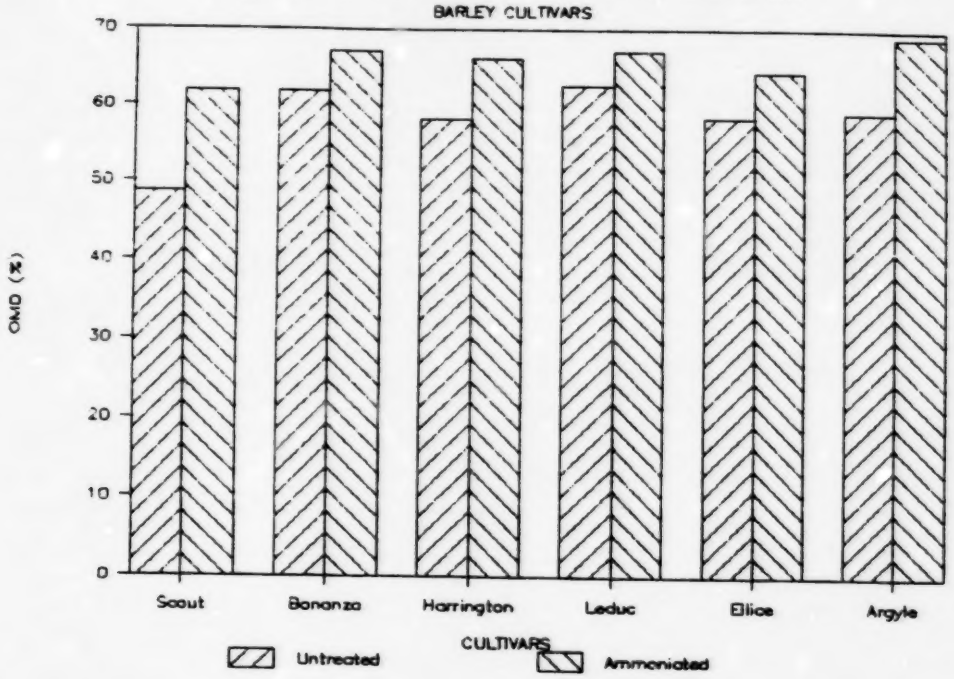
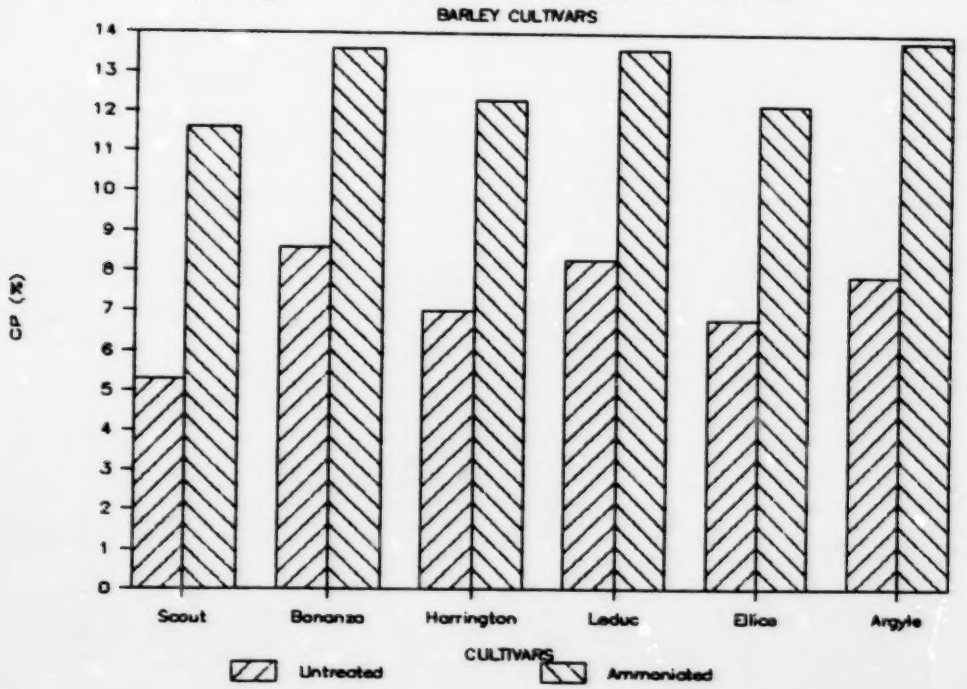


Fig. 4. Effect of ammonia on CP



Fragility Test

The fragility test did not distinguish between untreated and ammoniated chaff. The variability within each treatment was too high and the difference between treatments too small to make the test useful (Table 2).

Table 2. Fragility test on untreated and ammoniated rough awned chaff at 8.8% moisture.

Treatment	Fragility (%)	Standard Deviation
Ammoniated	37.8	1.4
Untreated	39.8	3.4
Significance of Treatment Effect	NS	-

Mastication Test

There was no significant effect of ammoniation on the grindability of Norwin awns. Both Katepwa and HY 320 chaff tend to become less fragile after ammonia treatment. This tendency is based on the results of the mastication test, where significantly more ammoniated chaff was left on coarser sieves for both cultivars. Norwin awns appear to be the easiest to grind and Katepwa chaff the most difficult (Table 3, Figs. 5, 6, 7).

Table 3. The effect of the artificial masticator on untreated and ammoniated HY 320 and Katepwa wheat chaff, and Norwin awns.

Sieve Size	% Total Recovery Retained on Sieve								
Cultivar	HY 320 Chaff			Katepwa Chaff			Norwin Awns		
Treatment	Unt	NH_3	Sig.	Unt	NH_3	Sig.	Unt	NH_3	Sig.
4	17	19	NS	35	56	**	2	1	NS
10	49	43	NS	38	28	NS	22	24	NS
18	15	24	**	20	7	**	28	25	NS
35	12	11	NS	5	5	NS	31	30	NS
60	7	3	NS	1	3	**	16	21	NS
Mean Total Recovery (g)	7.87	7.78	-	7.96	7.88	-	8.12	7.93	-

P<0.01

FIG. 5. AMMONIA ON HY 320 CHAFF

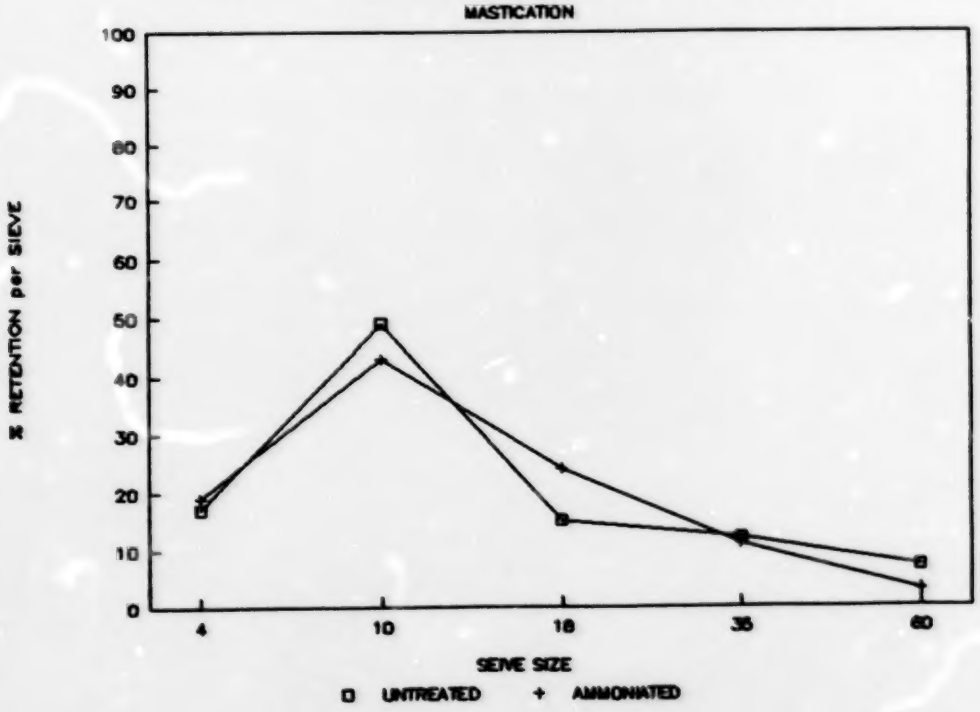


FIG. 6. AMMONIA ON KATEPWA CHAFF

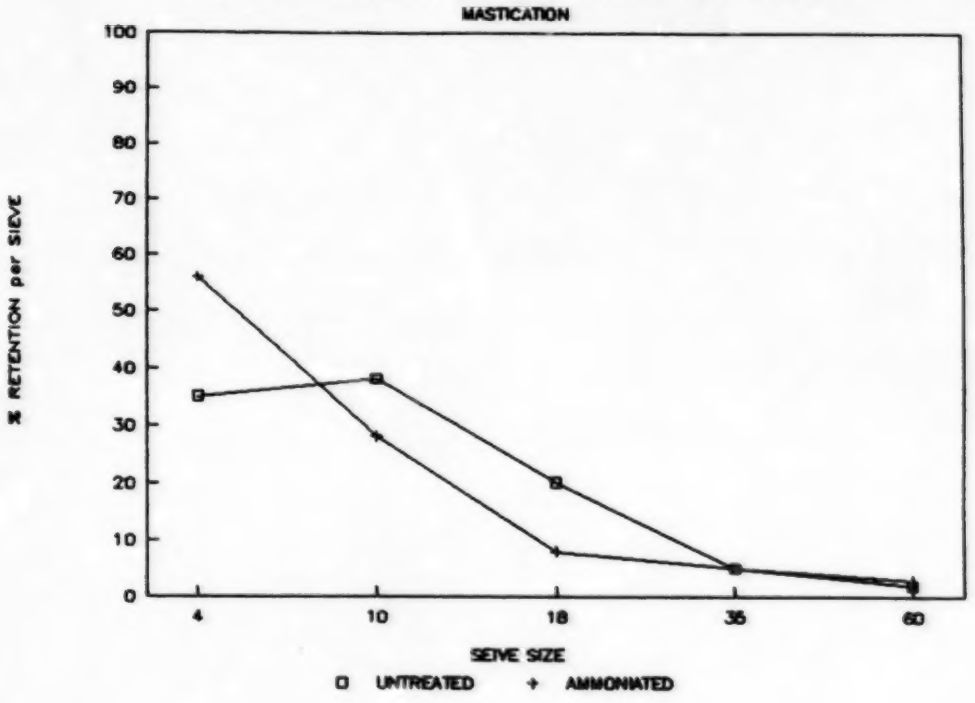
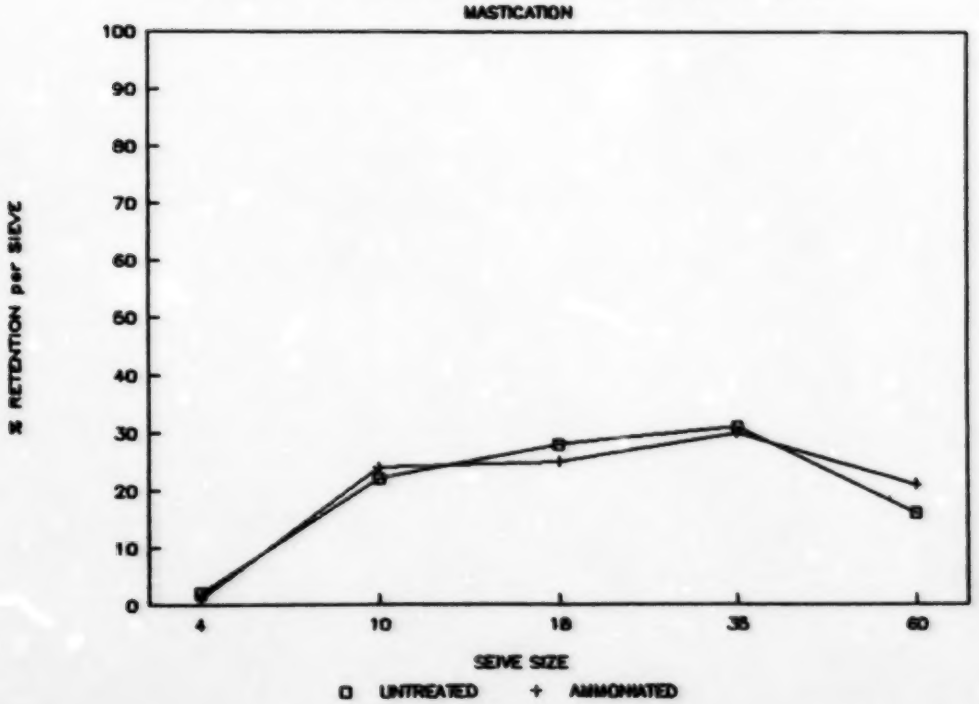


FIG. 7. AMMONIA ON NORWIN AWNS



The results of both the fragility test and the mastication test appear to indicate that ammonia treatment has little effect on the wet or dry grindability (fragility) of wheat chaff and awns, although it did tend to make Katepwa chaff more difficult to grind. The settling of a straw stack and a pile of chaff following ammoniation suggests that the physical effect of ammoniation may be a softening rather than an increase in fragility of the chaff particles.

ANIMAL TRIALS (1988 Crop Year)

MATERIALS AND METHODS

Chaff

Chaff was collected from farmers fields following harvest, using the Rem chaff collection system. For Katepwa wheat chaff, the chaff piles were picked up from the stubble field using a John Deere forage harvesting system. For the Wakooma durum wheat chaff, the piles were picked up with a front end loader equipped with forks and were loaded in grain trucks for movement to the Research Station. Each chaff was deposited in a pile on the ground and water was added to raise the moisture content to approximately 15%. The chaff piles were then divided into three equal portions which were subjected to the following treatments (Kernan and Knipfel 1981):

1. Untreated
2. 3.5% ammonia - uncovered
3. 3.5% ammonia - covered with plastic

The chaff piles were treated with ammonia the first week of September at an ambient temperature above 20°C. They were left for 6 weeks before beginning the animal experiments.

Sheep Digestibility Trial

Each chaff treatment was fed to 4 individually caged wethers in a randomized block design for 28 d, with feed intake determined daily for the duration of the test. Total fecal collection was undertaken for each wether for

7 d from day 21 to 28. Feed, refused feed, and feces were dried, ground and analyzed for organic matter (OM) and nitrogen (N) (AOAC 1973); energy by bomb calorimetry; cellulose (Crampton and Maynard 1938); neutral detergent fibre (NDF) and acid detergent fibre (ADF) (Goering and van Soest 1970); and IVOMD. The data were analyzed by accepted analysis of variance procedures for randomized block designs (Steel and Torrie 1960).

Cow feeding Trial

Two pens of 4 pregnant Hereford cows were fed each chaff in a randomized block design for a 75 day period from 8 December 1986 to 22 February 1987. Brome hay was fed to 2 additional pens of 4 animals each. Feed intake for the pens were recorded daily for the duration of the test period and refused feed was collected and sampled weekly. The cows were individually weighed at the beginning of the trial, on day 36 and at the conclusion of the test (day 75), with back fat measurements taken by ultrasonic probe at each weighing.

Steer Digestibility Trial

Each chaff treatment, as well as a good quality grass hay, was fed to 2 steers in metabolism stalls for a 21 d period with voluntary feed intake recorded daily. Prior to placement in the metabolism stalls, each animal was fed the test diet for 21 d (2 animals per pen). For the last 10 d of the metabolism stall feeding, 0.5% chromic oxide (Cr_2O_3) was fed to each steer, as

a percentage of the intake in the form of pelleted barley containing 10% Cr_2O_3. Total fecal collections were taken for the final 5 d of the digestion trial. Samples of feed and refused feed, as well as feces were analyzed for dry matter (DM), OM, N, energy, NDF, ADF, and cellulose by procedures earlier described. Chromic oxide was determined in feeds and feces (Hill and Anderson 1958). Digestibilities were calculated using the Cr_2O_3 ratio technique (Harris 1970).

RESULTS AND DISCUSSION

Laboratory analyses undertaken at the time of the wether digestion trial (Table 4) suggested that Wakooma durum wheat chaff was nutritionally superior to Katepwa wheat chaff, in terms of both N and IVOMD. Ammoniation increased the N and IVOMD of both chaffs and the increase was greater when the chaffs were covered with plastic (Table 4).

Analyses of samples taken approximately 1 year later when the steer digestion trial was conducted, had a considerably reduced N content. The chaff was covered (not sealed) with plastic and straw bales during the storage period. These data may have indicated inadequate sampling procedures, changes in N with time after ammoniation, or non-uniformity in the chaff piles. There were also substantial differences in IVOMD between samples taken for the sheep digestion trial and for the cow feeding trial. Further study revealed that extensive contamination with soil had occurred, particularly in the case of the Wakooma chaff. This was likely due to picking up the chaff piles from the field with the front end loader and is evident in the relatively high ash content of Wakooma NH_3-U fed in the steer digestion trial (Table 4, 100% - OM%). The chaff would be contaminated with less soil if a sweep or a chaff-o-matic had been used to pick up the chaff. High ash contents were also determined in many fecal samples (40-50%) and in many refused feed samples (60%). The extent to which this inclusion of soil may have influenced digestibilities is not certain at this time, but further investigation of potential effects is warranted.

Table 4. Composition of diets fed to wethers, cows and steers.

	OM	IVOMD	N	NDF	ADF	Cellulose
				(%)		
For Wether Digestion						
Katepwa	88.4	36.1	0.84	70.1	42.7	36.9
Wakooma	84.8	46.6	1.0	62.8	35.8	32.8
Katepwa NH_3-U	88.6	42.9	1.1	71.4	42.9	37.6
Wakooma NH_3-U	86.1	49.7	1.32	68.0	39.8	36.6
Katepwa NH_3-C	88.1	47.5	1.34	68.5	42.5	37.0
Wakooma NH_3-C	85.2	54.7	1.56	63.5	40.2	34.8
Brome Hay	92.1	51.0	1.26	65.3	39.0	34.5
For Steer Digestion						
Katepwa	86.9	-	0.88	67.7	43.8	36.8
Wakooma	81.7	-	0.74	63.5	41.4	35.0
Katepwa NH_3-U	86.4	-	0.97	69.3	42.4	36.1
Wakooma NH_3-U	73.8	-	0.52	63.4	36.8	31.2
Katepwa NH_3-C	88.2	-	0.81	72.2	45.7	38.1
Wakooma NH_3-C	85.6	-	1.03	66.6	41.6	36.2
Brome Hay	91.3	-	1.31	68.6	39.1	34.3
For Cow Feeding						
Katepwa	89.1	54.2				
Wakooma	88.2	44.1				
Katepwa NH_3-U	90.7	46.9				
Wakooma NH_3-U	89.9	49.2				
Katepwa NH_3-C	87.9	40.8				
Wakooma NH_3-C	87.8	54.0				
Brome-alfalfa						
Brome Hay	90.8	52.3				

U-uncovered
C-covered

Digestibility coefficients determined with wethers showed the enhancing effect of ammoniation upon organic matter digestibility (OMD), nitrogen digestibility (ND), and energy digestibility (ED)[1], although in many instances the effects were not statistically significant (Table 5). A similar observation occurred when digestible nutrient contents (Table 6) are examined. The lack

Table 5. Digestibility coefficients for chaff treatments[2] as determined with wethers.

Constituent	Brome Hay	Diet Fed: Katepwa			Wakooma			$S_{\bar{x}}$
		Unt[3]	NH_3 U[4]	NH_3 C[5]	Unt	NH_3 U	NH_3 C	
OMD (%)	57.5^{ab}	48.3^{b}	53.3^{ab}	54.2^{ab}	52.4^{ab}	57.3^{ab}	62.4^{a}	2.2
ND (%)	45.2	38.7	42.0	41.1	45.6	50.5	54.6	7.7
CelD (%)	63.7^{abc}	58.3^{c}	59.8^{c}	63.5^{abc}	60.8^{bc}	69.0^{ab}	71.8^{a}	2.0
NDFD (%)	60.9^{ab}	53.0^{b}	55.2^{b}	60.3^{ab}	59.1^{ab}	65.5^{a}	69.2^{a}	2.3
ADFD (%)	59.9^{ab}	52.4^{b}	52.5^{b}	59.5^{ab}	57.1^{ab}	62.9^{a}	66.8^{a}	2.3
ED (%)	53.0	47.2	50.0	50.8	49.0	53.2	55.1	2.4

[2]-Means with same or no superscript in same row are not significantly different ($P<0.05$)
[3]-Untreated
[4]-Uncovered
[5]-Covered

[1] Cellulose digestibility (CelD)
Neutral detergent fiber digestibility (NDFD)
Acid detergent fiber digestibility (ADFD)

Table 6. Digestible nutrient contents for chaff treatments[1] as determined with wethers.

Constituent	Brome Hay	Diet Fed: Katepwa Unt[2]	Katepwa NH_3 U[3]	Katepwa NH_3 C[4]	Wakooma Unt	Wakooma NH_3 U	Wakooma NH_3 C	$S_{\bar{x}}$
DOM (%)	49.8^{a}	35.1^{c}	38.8^{bc}	40.9^{abc}	39.4^{ab}	40.0^{ab}	47.4^{ab}	2.1
DN (%)	0.60^{ab}	0.35^{b}	0.43^{b}	0.45^{b}	0.60^{ab}	0.70^{ab}	0.88^{a}	0.08
DCel (%)	22.1^{b}	21.3^{bc}	19.8^{c}	23.8^{b}	22.3^{bc}	25.7^{ab}	28.4^{a}	0.87
DNDF (%)	40.6^{bc}	37.7^{bc}	35.5^{c}	43.4^{ab}	40.8^{bc}	46.3^{ab}	49.1^{a}	1.72
DADF (%)	24.1^{b}	22.8^{bc}	19.2^{c}	25.7^{ab}	24.3^{b}	25.6^{ab}	29.9^{a}	1.07
DE (%)	2.30	1.95	1.95	2.08	2.02	2.10	2.15	0.10

[1]-Means with same or no superscript in same row not significantly different ($P<0.05$)
[2]-Untreated
[3]-Uncovered
[4]-Covered

of statistical significance may be due to high standard errors of estimate ($S_{\bar{x}}$) which may have resulted from variation in the feeds composition due to soil contamination. The digestibility (OMD) of both chaffs is reduced considerably when the ash contents are taken into consideration (DOM) (Tables 5 and 6). Ammoniation increased the digestibility of the various fibre fractions (NDFD, ADFD, CelD), while there was little effect upon ND (Table 5). These data further confirm that ammoniation should not be considered primarily as a method of N supplementation, but rather as a means of improving energy

availability. Intakes of various constituents (Table 7) emphasizes that ammoniation may improve both the intake of DN as well as energy related constituents. The covering of chaff piles with plastic appeared to improve the efficiency of the ammoniation reaction over that observed when non-covered chaff piles were ammoniated (Table 7).

Table 7. Consumption of digestible constituents[1] of chaff treatments as determined with wethers.

Constituent ($kg^{-0.75}$)	Diet Fed: Brome Hay	Katepwa Unt[2]	Katepwa NH_3 U[3]	Katepwa NH_3 C[4]	Wakooma Unt	Wakooma NH_3 U	Wakooma NH_3 C	$S_{\bar{x}}$
CDOM (g)	33.2^{ab}	18.5^{c}	22.4^{c}	26.3^{bc}	25.7^{bc}	26.1^{bc}	36.7^{a}	2.2
CDN (g)	0.35^{b}	0.15^{c}	0.20^{bc}	0.28^{bc}	0.35^{b}	0.38^{ab}	0.55^{a}	0.04
CDCel (g)	13.8^{ab}	9.2^{b}	9.5^{b}	13.0^{b}	13.1^{b}	12.6^{b}	17.9^{a}	1.0
CDNDF (g)	25.4^{ab}	17.8^{b}	17.0^{b}	23.7^{ab}	23.6^{ab}	23.1^{ab}	30.9^{a}	1.9
CDADF (g)	15.1^{ab}	9.8^{c}	9.2^{c}	14.1^{abc}	13.1^{bc}	13.8^{abc}	18.8^{a}	1.1
CDE (kcal)	142.0^{a}	85.1^{b}	92.1^{b}	114.0^{ab}	105.2^{ab}	114.4^{ab}	134.7^{a}	8.46

[1]-Means with same or no superscript in same row not significantly different ($P<0.05$)
[2]-Untreated
[3]-Uncovered
[4]-Covered

Wakooma durum wheat chaff, untreated and ammoniated without a cover, resulted in weight losses when fed as the sole diet in the cow feeding

trial (Table 8). This occurred in spite of the apparent superiority of Wakooma durum wheat chaff over Katepwa wheat chaff (Table 7). The effect may be at least partially attributed to lower feed intakes (Table 8). Ammoniation did improve the nutritive values of the chaffs as evidenced by higher gains or less losses than for the untreated chaffs. The additional nutritional benefit from covering the chaff piles was again obvious. In all groups there was a loss of back fat over the course of the study (Table 8), with the extent of losses in back fat apparently unrelated to weight gains or losses.

Table 8. Performance of pregnant beef cows fed awned and non-awned chaff and the effect of ammoniation.

Diet	Weight Gain		Feed Intake	Back Fat (mm)	
	kg	kg d^{-1}	kg d^{-1}	Initial	Final
Brome-alfalfa Hay	26.3	0.34	9.1	8.5	7.5
Katepwa Wheat Chaff	3.4	0.05	9.2	6.8	5.2
Wakooma Wheat Chaff	-15.5	-0.20	7.2	7.9	5.4
Katepwa-NH_3-U[1]	14.0	0.18	12.1	11.1	7.3
Katepwa-NH_3-C[2]	9.0	0.12	11.1	9.8	6.5
Wakooma-NH_3-U	-9.0	-0.11	8.1	9.9	6.6
Wakooma-NH_3-C	29.2	0.37	7.8	10.9	9.0

[1]-Uncovered
[2]-Covered

Digestibility determination of the various chaffs with steers suggested that ammoniation had little effect on the Katepwa chaff, but gave marked improvement on the Wakooma chaff (Table 9). This was particularly true for ED and OMD. Associated with these increases were increases in digestibility of the fibre fractions. No apparent explanation can be given for this discrepancy with the data from Table 5, but the time lag of 1 year between the 2 digestibility trials may have allowed reversal of the ammoniation effect. However, it would be expected that both chaffs would decrease to pre-ammoniation levels, if a simple reversal of the ammoniation reactions were involved and would become more susceptible to fungal and bacterial attack.

Table 9. Digestibility coefficients for chaff treatments as determined with steers.

Constituent		Brome Hay	Diet Fed: Katepwa Unt[1]	Katepwa NH_3-U[2]	Katepwa NH_3-C[3]	Wakooma Unt	Wakooma NH_3-U	Wakooma NH_3-C
OMD	(%)	60.1	59.8	60.0	57.1	52.5	57.4	65.2
ND	(%)	46.6	44.6	47.6	40.1	37.5	42.3	43.5
CelD	(%)	69.1	69.0	69.7	67.4	64.9	71.5	73.7
NDFD	(%)	67.3	63.6	66.7	64.8	58.6	68.8	71.3
ADFD	(%)	63.5	63.4	64.7	62.8	59.8	54.7	69.7
ED	(%)	56.3	56.7	57.4	56.5	49.9	53.8	62.8

[1]-Untreated
[2]-Uncovered
[3]-Covered

While there was no apparent increase in DE due to ammoniation (Table 10), it is of interest that these DE values should be adequate to provide maintenance of a pregnant cow, and in the cow feeding trial the Katepwa chaffs all provided positive gains (Table 8). Conversely, both the Wakooma chaffs which resulted in weight losses of cows had the lowest DE contents observed. These data are, however, inconsistent with the intakes of DE (Table 11). Many studies have suggested that maintenance DE requirements of approximately 125 kcal $kg^{-0.75}$ are adequate. This value was achieved by all diets fed in this study. The ND intakes for Wakooma durum chaff, either untreated or ammoniated and uncovered, were lower than for the other diets (Table ll). This suggests that weight losses might have resulted from a combination of inadequate DN and DE intakes together.

There was considerable variation exhibited among animals and among the different studies undertaken, which likely masked real differences. A repeat of these studies with improved chaff collection procedures is necessary to fully elucidate the effects observed.

These studies have demonstrated the beneficial effect of ammoniation of wheat chaffs, both awned and non-awned. There was little indication that awned chaff was less readily accepted than the non-awned chaff, by either wethers or steers, in contrast to earlier studies. Covering chaff piles prior to ammoniation appears to offer an incremental benefit over that of ammoniation alone. The nutritive value of ammoniated chaff will increase slowly and it can be preserved indefinitely it is sealed in plastic during storage (Kernan et

al. 1989). The economic consequences of these procedures need to be further studied.

Table 10. Digestible nutrient contents for chaff treatments as determined with steers.

Constituent		Brome Hay	Diet Fed: Katepwa			Wakooma		
			Unt[1]	NH_3-U[2]	NH_3-C[3]	Unt	NH_3-U	NH_3-C
DOM	(%)	54.9	52.0	51.9	50.3	42.9	42.4	55.8
DN	(%)	0.61	0.39	0.47	0.32	0.28	0.22	0.45
DCel	(%)	23.7	25.4	25.2	25.7	22.7	22.3	26.7
DNDF	(%)	46.2	43.1	46.2	46.8	37.2	43.6	47.5
DADF	(%)	24.8	27.8	27.5	28.7	24.8	23.8	29.0
DE	(%)	2.42	2.24	2.25	2.29	2.09	1.77	2.44

[1]-Untreated
[2]-Uncovered
[3]-Covered

Table 11. Consumption of digestible constituents of chaff treatments as determined with steers.

Constituent ($kg^{-0.75}$)		Brome Hay	Diet Fed: Katepwa Unt[1]	Katepwa NH_3-U[2]	Katepwa NH_3-C[3]	Wakooma Unt	Wakooma NH_3-U	Wakooma NH_3-C
CDOM	(g)	45.3	40.6	39.5	35.5	23.6	31.4	48.4
CDN	(g)	0.50	0.31	0.36	0.23	0.20	0.16	0.39
CDCel	(g)	19.7	19.8	19.1	18.2	11.3	16.5	23.2
CDNDF	(g)	38.2	33.7	35.2	33.0	26.7	32.2	41.2
CDADF	(g)	20.5	21.7	20.9	20.2	17.8	17.6	25.2
CDE (kcal)		199.6	125.0	171.2	161.6	149.8	123.4	211.7

[1]-Untreated
[2]-Uncovered
[3]-Covered

PHASE II - 1989 CROP YEAR

MATERIALS AND METHODS

Chaff

Wascana durum chaff was collected using the Rem collection system and was picked up from the field using a front end loader. The chaff was piled on the ground and treated with ammonia on 27 November 1989 as described by Kernan and Knipfel (1990). The maximum and minimum temperatures at Swift Current that day were -7°C and -11°C respectively. The chaff was left uncovered for four months prior to beginning the digestibility trials.

Columbus hard red spring wheat chaff was collected near Rosetown and transported to Jadway Farms where water was added prior to ammoniation to bring the chaff moisture content to more than 20%. Insufficient untreated chaff was available to feed the steers in the digestibility trial, so only sheep results are available. The chaff was transported to the Swift Current Research Station for animal trials approximately four months after ammoniation. It had been stored uncovered.

Sheep Digestibility Trial

Each chaff treatment was fed to four individually caged yearling ewes in a randomized complete block design for 28 days. Feed intakes were determined daily for the duration of the test, and total fecal collection was undertaken from day 21 to day 28 for each ewe. Feed, refused feed, and feces

were dried, ground, and analyzed for OM, N, energy, cellulose, NDF, ADF, and IVOMD. The data were analyzed by established analysis of variance procedures for randomized block designs (Steel and Torrie 1960). The nutritive values of brome hay fed to an additional group of ewes is included in Tables 13, 14, and 15, but was not included in the statistical analyses.

Steer Digestibility Trial

Each chaff treatment was fed to four individually caged yearling steers in a randomized block design for 28 days. Feed intakes were determined daily and total fecal collections taken daily from day 21 to day 28. Feeds, feces, and refused feeds were dried, ground, and analyzed for OM, N, cellulose, energy, NDF, and ADF as described for the sheep digestibility trial immediately preceding. The nutritive values of brome hay fed to an additional group of steers is included in Tables 16, 17, and 18, but was not included in the statistical analyses.

RESULTS AND DISCUSSION

Feed composition

The untreated Wascana durum chaff was slightly lower in % N than the untreated Columbus hard red spring wheat chaff (Table 12), and following ammoniation was considerably lower. Ammonia treatment failed to raise the % N of either chaff to levels equal to that of brome hay, although the ammoniated Columbus chaff used for the sheep trial was only slightly lower. Differences in composition of the same chaffs fed to ewes and steers (Table 12) demonstrate the variability encountered within a chaff supply.

Table 12. Composition of Chaff Fed to Wethers and Steers (DM basis).

	% OM	% N	% IVOMD	% NDF	% ADF	% Cellulose
Ewe Digestion						
Wascana	88.9	1.09	43.8	68.3	38.0	33.3
Wascana-NH_3	84.7	1.58	40.9	62.5	37.4	32.1
Columbus	90.7	1.22	46.1	61.0	35.3	29.2
Columbus-NH_3	87.9	2.23	57.1	57.2	44.0	37.7
Alfalfa-Brome Hay	90.6	2.53	61.3	49.1	30.7	28.9
Steer Digestion						
Wascana	87.2	1.01	40.7	66.4	39.9	33.9
Wascana NH_3	87.9	1.53	46.1	64.1	38.5	32.2
Columbus NH_3	89.0	1.76	51.1	63.1	45.3	40.0
Alfalfa-Brome Hay	90.6	2.53	61.3	49.1	30.7	28.9

Sheep Digestibility Trial

Ammoniation of the awned Wascana durum chaff had no effect upon digestibility coefficients for any chaff components except ND (Table 13). This was likely a consequence of insufficient moisture in the chaff (approximately 10%) during ammonia treatment. Although the ND of the chaff was increased substantially by ammonia treatment, this increase was not statistically significant.

Table 13. Digestibility Coefficients for Components of Chaff Fed to Sheep.

Constituent	Alfalfa Brome Hay	Wascana		Columbus		$S_{\bar{x}}$
		Untreated	Ammoniated	Untreated	Ammoniated	
OMD (%)	62.9	54.4^{b}	49.4^{b}	59.6^{b}	78.2^{a}	2.66
ND (%)	70.3	28.9^{b}	48.8^{b}	47.2^{ab}	64.0^{a}	4.97
CelD (%)	63.6	63.4^{b}	59.6^{b}	64.8^{b}	86.0^{a}	2.41
ED (%)	58.6	51.3^{b}	45.6^{b}	52.9^{b}	74.9^{a}	3.24
NDFD (%)	56.9	60.3^{b}	53.7^{b}	59.7^{b}	82.9^{a}	2.59
DFD (%)	54.8	53.5^{b}	49.3^{b}	56.4^{b}	76.6^{a}	2.51

Means within same row with same or no superscript are not significantly different ($p>0.05$).

The digestibility of components of the non-awned Columbus wheat chaff were markedly improved by ammoniation, and except for ND, all increases were statistically significant. The in vivo OMD of ammoniated Columbus chaff is considerably high than its in vitro OMD (Tables 12 and 13). The effect of ammonia on fibre digestibility is demonstrated by the improvements

in the digestibilities of the fibre components, cellulose, NDF, and ADF. The moisture content of the Columbus chaff was sufficient to permit the optimum ammoniation effect.

The digestible component contents of both chaffs, and for the awned chaff in particular, were somewhat lower than expected (Table 14). This reflects the high level of non-organic material (ash) in the chaff (Table 12, 100%-OM%). This high ash level is due to relatively large amounts of soil in the chaff and makes if difficult to obtain accurate and consistent measurements of nutritive value. The Columbus chaff was initially of higher nutritive quality than the awned chaff, and since it contained adequate moisture, was much more responsive to ammonia treatment (Table 14).

Table 14. Digestible Nutrient Contents of Chaff Fed to Sheep

Constituent	Alfalfa-Brome Hay	Wascana		Columbus		$S_{\bar{x}}$
		Untreated	Ammoniated	Untreated	Ammoniated	
DOM (%)	54.4	39.7^{b}	34.9^{b}	46.6^{b}	63.9^{a}	2.86
DN (%)	1.82	0.35^{b}	0.81^{b}	0.61^{b}	1.86^{b}	0.25
Cel (%)	18.2	20.1	19.3	18.3	27.5	2.47
DE (kcal g^{-1})	2.50	2.10^{b}	1.81^{b}	2.12^{b}	2.92^{a}	0.13
DNDF (%)	27.5	40.9	34.5	35.6	41.80	3.25
DADF (%)	16.5	19.8^{ab}	18.7^{b}	19.3^{b}	29.21^{a}	2.15

Means within same row with same or no superscript are not significantly different ($P<0.05$).

Digestible nutrient intakes by the sheep (Table 15) were considerably lower for all chaff treatments than those observed in the earlier study (Table 7). There was also a considerable variation among sheep in voluntary intake (Tables 7 and 14 $S_{\bar{x}}$). The intake of DN for awned chaff increased on ammoniation to the same intake observed for the ammoniated non-awned chaff (Table 15). This occurred even though the ammonia treatment did not appear to cause large increases in fibre digestion. This suggests that there may be an intake enhancing effect of ammoniation due to the presence of N which is not a consequence of increased fibre digestion. This effect would be similar to that shown by other protein supplements in increasing intake of low quality roughages, but needs further investigation to determine the partitioning of effects due to N presence alone and due to increased fibre digestibility.

Ammoniation of the Columbus wheat chaff improved digestibility (Table 13) and digestible content (Table 14) of OM, DE, and the fibre components to levels equal to or greater than the brome hay. However, this was not reflected in the consumption data (Table 15), as it was for Phase I (Table 7) as the chaff intakes were all considerably lower than the hay intakes. At present, we have no explanation for this apparent anomaly.

Table 15. Digestibility Nutrient Intakes by Sheep Fed Chaff.

Constituent ($kg^{-0.75}$)	Alfalfa-Brome Hay	Wascana		Columbus		$S_{\bar{x}}$
		Untreated	Ammoniated	Untreated	Ammoniated	
DOM (g)	50.8	14.3	16.9	20.3	16.9	3.57
DN (g)	1.62	0.11[b]	0.32[ab]	0.23[ab]	0.34[a]	0.05
Cel (g)	16.0	5.9	7.7	6.8	10.2a	1.85
DE (kcal)	222.4	62.1	72.5	78.3	86.5	14.1
DNDF (g)	24.6	12.0	13.7	13.3	15.0	2.74
DADF (g)	14.7	5.9	7.4	7.2	10.3	1.81

Means within same row with same or no superscript are not significantly different ($P<0.05$).

Steer Digestibility Trial

Ammoniation of the Wascana durum chaff caused an increase in ND, but there was a decline in the digestibility coefficients for all other components in the steer diet (Table 16). The ammoniated Columbus chaff was considerably higher in nutritive value than the Wascana durum chaffs and appeared to be equal to the hay except for ND (Table 16). The apparent decline in digestibility coefficients following ammoniation of the Wascana chaff (Table 16) observed with steers was similar to that for the sheep (Table 14).

Table 16. Digestibility Coefficients for Nutrients in Chaffs Fed to Steers.

Constituent		Alfalfa-Brome Hay	Wascana		Columbus	$S_{\bar{x}}$
			Untreated	Ammoniated	Ammoniated	
OMD	(%)	65.4	50.9^{ab}	40.8^{b}	64.9^{a}	3.43
ND	(%)	67.8	6.9	24.5	29.7	5.85
CelD	(%)	71.1	64.3^{ab}	52.0^{b}	76.8_{a}	2.89
ED	(%)	60.5	45.9^{ab}	37.9^{b}	59.2^{a}	3.64
NDFD	(%)	63.7	51.9^{b}	47.9^{b}	72.8^{a}	4.30
ADFD	(%)	63.2	55.1^{ab}	43.7^{b}	65.3^{a}	2.81

Means within same row with same or no superscript are not significantly different ($P<0.05$).

Digestible N contents (Table 17) of the ammoniated chaffs were increased markedly and exceeded that of the brome hay fed to steers. In spite of the increased uptake of N for the ammoniated Wascana durum chaff and its apparently relatively high availability, this effect was not accompanied by an increase in availability of other components. The ammoniated Columbus chaff, on the other hand, appeared to have a digestible energy content approaching that of the brome hay (Table 17).

Table 17. Digestible Nutrient Contents of Chaffs Fed to Steers.

Constituent	Alfalfa-Brome Hay	Wascana		Columbus	$S_{\bar{x}}$
		Untreated	Ammoniated	Ammoniated	
DOM (%)	56.9	33.8^{ab}	27.8^{b}	48.3^{a}	3.52
DN (%)	1.71	0.41^{b}	2.38^{ab}	3.28^{a}	0.081
DCel (%)	20.3	23.4^{b}	16.3^{c}	32.6^{a}	1.11
DE (kcal g^{-1})	2.6	1.83^{ab}	1.53^{b}	2.41^{a}	0.147
DNDF (%)	31.1	37.9^{ab}	31.0^{b}	47.9^{a}	3.49
DADF (%)	19.4	23.7^{b}	16.7^{c}	31.1^{a}	1.28

Means within same row with same or no superscript are not significantly different ($P<0.05$).

Intakes of digestible energy by steers fed all the diets (Table 18) were markedly higher than those for the ewes (Table 14) and were similar to those observed in the first phase of this study (Table 11). The intakes of DE were above suggested maintenance levels of 125 kcal $kg^{-0.75}$ for all steer diets, which indicates that untreated Wascana chaff was an adequate maintenance ration for a pregnant beef cow.

Table 18. Digestible Nutrient Intakes by Steers fed Chaffs.

Constituent ($kg^{-0.75}$)	Alfalfa-Brome Hay	Wascana		Columbus	$S_{\bar{x}}$
		Untreated	Ammoniated	Ammoniated	
DOM (g)	69.2	37.9	32.8	45.2	5.19
DN (g)	1.98	0.07	0.35	0.40	0.09
DCel (g)	23.7	18.7	14.9	24.0	2.2
DE (kcal)	300.1	148.7	140.1	179.1	25.0
DNDF (g)	36.4	30.4	28.3	35.5	3.70
DADF (g)	22.6	19.1	15.3	23.0	2.37

Means within same row with same or no superscript are not significantly different ($P<0.05$)

There was considerable variation in measured digestibilities and intakes among animals fed the same diet in both phases of this study which tends to obscure real differences as measured statistically. This variation appears to be an intrinsic feature of crop residues (both straw and chaff) collected on a field scale, and raises some important questions regarding the ability to accurately assess the nutritive values of these feedstuffs. Collection of truly representative samples for nutritive evaluation of chaff remains a serious deterrent to accurate ration formulation. It is of interest that a combination of treated crop residues with good quality hays or grain can markedly improve intakes and DOM (Brandt and Klopfenstein 1986, 1986a).

There is no apparent explanation for the wide difference in nutritive evaluation of the chaff between steers and ewes. However, a similar effect was observed with awned chaffs in preliminary studies done a number of years ago (Knipfel unpublished). This clearly demonstrates potential dangers in using digestibility trial data for sheep to estimate nutritive values of chaff for cattle. While the relative rankings for digestibility and digestible nutrient contents remained the same for ewes (Tables 13 and 14) and steers (Table 16 and 17) the wide differences in intake must be accounted for when attempting to extrapolate from sheep to cattle. This finding is consistent with earlier observations that cattle appear to utilize low quality roughages more readily than do sheep. This effect may be primarily a consequence of voluntary intake due to palatability, or due to more efficient movement of the material through the digestive tract, but the exact reason(s) are not presently known.

An additional concern observed in this study was the lack of consistency of intake between the wethers fed chaff in Phase I and the ewes fed chaff in Phase II. Since the digestibilities were not markedly different, the wide differences in intake suggest that factors other than digestibility were affecting the palatability of the chaffs.

The wide difference between steers and ewes in digestible nutrient intakes was also evident when the same hay was fed (Tables 15 and 18). Since other studies have not revealed such wide differences for hay diets, this suggests that for some reason, the ewe intakes were low. Therefore, the validity of the data on intake of digestible nutrients by sheep in Phase II is

open to question, even though the digestibility data appear to be consistent with other aspects of the study.

Adequate moisture is necessary to permit the ammoniation reaction to increase the availability of energy to the ruminant. An increase in N digestibility resulting from ammoniation at low moisture content, might assist in correction of inadequate dietary N availability. However, the lack of increased energy availability renders the ammoniation process an inefficient and costly means of only providing N supplementation.

CONCLUSIONS

1. Rough awns in chaff from durum wheats do not appear to affect intake by cattle, but may be the factor causing reduced intakes by sheep.
2. Adequate moisture (20% or greater) is absolutely necessary to improve the digestible energy available to either sheep or cattle.
3. Chaff ammoniated under a cover has a somewhat higher nutritive value than chaff ammoniated without a cover. This was especially true for Wakooma chaff (Phase I) as it had much higher digestibility and intake values than chaff treated without a cover.
4. The high variability in crop residues, including chaff, makes it difficult to obtain representative samples and thus to accurately formulate rations.
5. It may not be advisable to use digestibility trial data for chaff fed to sheep to estimate nutritive values of chaff for cattle. This may be true for other low quality roughages also.
6. Care must be taken to reduce the contamination of chaff with soil when it is being picked up or formed into a pile.

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